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Why Bells sound out of Tune

and

How to Cure them

By Barwick
Rev. ARTHUR B. SIMPSON, M.A.
Rector of Fittleworth, Sussex,
and Rural Dean

London
Skeffington & Son, Piccadilly, W.
Publishers to H.M. the Queen and to H.R.H. the Prince of Wales
1897

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NOTICES OF THESE PAPERS.

"Ought certainly to be read by the musical public . . . If Mr. Simpson is mistaken in his views, then let bell-founders arise and confute him; but if he is correct in his statement and interpretation of facts, to him may belong the honour of inaugurating a new departure in English Bell Founding."—*Guardian.*

"A new departure."—*A Bell Founder.*

"I have read your paper with interest, you make out a strong case."—F. R. S.

"A marvel of lucidity."—*Editor.*

"A charming work of art."—C. B.

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Introduction.

THE following Papers appeared first of all in the *Pall Mall Magazine* (October, 1895, and September, 1896), where they attracted a good deal of attention, which has led to my receiving many interesting letters of enquiry from bell experts, as well as from others to whom the subject was new and interesting.

It is significant that, among the various notices and letters which have reached me, there is not one that contains any contradiction, or even criticism of the facts and conclusions advanced in these papers. There is much flattering appreciation of the "lucidity," and importance of their contents, but it is evident (as I anticipated) that they have proved to be generally new and unstudied, and, in short, they have been accepted (to use the words of a well-known expert) as a "new departure."

I have the great satisfaction of knowing that several eminent bell-founders have taken up the matter in a practical manner. In particular I should mention Messrs. Taylor, of Loughborough, who were the first to appreciate the importance of the ideas which I have advocated, and who have faced the task of carrying them out to a practical issue with an energy and intel-

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ligence deserving of all praise. It is with no small pride that I quote these words from a recent letter from them :—

"The fact is that we are tuning all our bells on the lines you have laid down, and we can guarantee to have the hums, fundamentals, and nominals strictly in tune, and of course all the bells in tune with each other."

Messrs. Barwell, also, the well-known founders of Birmingham, are engaged in the determined effort to avail themselves of any light which these papers may supply for the gradual improvement of the harmony of their bells.

This is well; but I beg very earnestly to repeat here what I have said elsewhere—that any general advance in this respect must depend very largely on the *demand* made by the musical public (and especially by incumbents and churchwardens) for greater perfection in the bells supplied to them.

As long as they are unable to discriminate, it is not likely that bell-founders—who, after all, are but men—will expend time, trouble, and money in the attainment of an ideal, and unrecognised perfection.

It is therefore mainly in the hope of interesting and instructing the *public* that I venture to reprint these papers (with some unimportant alterations, and some not unimportant additions) in a more generally accessible form.

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Why Bells sound out of Tune.

On Bell Tones.

I.

I HAVE nothing to say on the ancient history of bells, nor shall I attempt to make any addition to the many pretty things which have been said as to their sentimental power. My object is more prosaic. It is simply to place on record certain facts which have come under my notice, during a course of observation extending over many years, and which I have reason to think would prove interesting to many.

We have the bells with us everywhere, and few people with musical ears have not, at one time or another, amused themselves, and (I will venture to suggest) *puzzled* themselves, in attempting to determine accurately the notes of their own church bells.

Many of us, also, have been struck by the apparent want of harmony in the famous carillons of Bruges and other Belgian towns; and some few have been at great expense to set up carillons of their own, and have

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been reluctantly driven to the vexatious conclusion that they are "painfully out of tune."

To all these I think I have that to say which will interest them. And I am not without hope that, through their influence, our bell founders and tuners may be roused to study their work more closely, to try to understand better what was the purpose of the original designers of the present form of bell, and endeavour to fulfil that purpose more nearly than they have done in the past.

I begin by boldly asserting, as the result of a pretty wide experience, that there is hardly a bell in England that is really "in tune *with itself*," and most certainly not a single "peal" of bells that are properly in tune with each other.

I do not say that there are not many peals which are in excellent tune as to the most important note in each, and their general musical effect very pleasing. But I do assert that the best of these might be much better; and, in the majority of cases, the irregularities I complain of are such as seriously to mar their musical effect, and such as ought to be, and might be avoided by more intelligent founding, or (in most cases) rectified by more intelligent tuning after founding.

Now, this whole matter turns on the meaning of the expression "in tune with itself." Most people have an idea that every bell has one prominent unmistakable note which characterises it, and as to whose pitch no two people with musical ears could differ. Thus, in the article on Bells in the latest edition of the *Encyclopædia*

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Britannica, we read the following: "A good bell when struck yields one note, so that any person with an ear for music can say what it is."

If for "a good bell" we may read "a bell in good tune," this statement is true; but, as it stands, it condemns as "not good" some of the finest and best bells in the world.

One example, and that a notable one, will suffice at present to support me in this.

In the *Times* of July 20th, 1887, there is an account of the "inauguration" of the great bell "Gloriosa," made out of French cannon and hung in the Cathedral of Cologne. The account concludes thus: "The opinions of experts are divided as to whether the note which the bell sounds is C sharp or D."

I feel sure that many of my readers have felt a similar difficulty in determining the note of a familiar bell.

Now, to account for this and to clear the way for further observations, we must understand what is the true "theory" of a bell, if I may be allowed the expression.

It would surely be unreasonable to suppose that the very peculiar form of bell which (with slight modifications) has been preserved for so many hundreds of years, both here and on the Continent, was adopted without the deliberate purpose of ensuring that the various tones and sub-tones of each bell should be in some fixed musical relation to each other.

What is that relation?

I make bold to suggest that it is this: Every true

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bell should give out, when fairly struck, a fundamental note or "tonic," its third, fifth, and octave above, and its octave below, thus sounding the full chord—*do, mi, sol, do,* with the bass *do* below.

This is the "theory" which was, I am satisfied, before the minds of the original designers of the present form of bell. Almost forgotten (if ever realised) by many of their successors, it is still recognised by some, and irresistibly forced upon the acceptance of those who, like the present writer, have made a study of the tones of bells as they are.

The following extract from the article on Founding of Bells in the *Encyclopædia Britannica*, 5th Edition, 1815, though misleading in several respects, is of importance as showing that such a theory was recognised in this country not so very long ago, though, it is true, there is no reference to the lowest note we have spoken of.

"The height of the bell in proportion to its diameter (is) as 12 to 15, or in the proportion of the fundamental sound to its third major: whence it follows (?) that the sound of a bell is principally composed of the sound of its extremity, or brim, as a *fundamental*—of the sound of the crown, which is an *octave* to it—and of that of the height, which is a *third*."

But now, to bring this paper within reasonable limits, we must dismiss all consideration of thirds and fifths, and confine our attention to the three more important notes—*i.e.*, the tonic, its octave above, and its octave below. For convenience' sake, and for reasons which will appear further on, let us call the first of these the

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"fundamental," the second (or octave above) the "nominal," and the third (or octave below) by the name by which it is known in English foundries, the "hum-note."

If, then, a bell corresponded to its "theory," these three would sound the same note, in three consecutive octaves, and the bell would, so far, be "in tune with itself."

But, alas! where shall we find such a bell? Whatever the cause may be—whether founders, in ignorance or indifference as to the importance of having these notes in accord, have, (1) for convenience of *ringing*, altered the original proportions of bells, or, (2) to obtain greater power, put more metal into them—certain it is that it is quite the exception to find a bell which has *any two* of these notes in unison, and rare indeed to meet with *one* in which *all three* are in accord.

By far the commonest state of things is this: The "fundamental" is almost always the flattest of the three—irrespective, of course, of octave. The "hum-note" is almost always the sharpest, and the "nominal" generally between the two. Thus, if the nominal of a bell is C, the fundamental will probably be somewhere between C and B in the octave below, while the hum-note will probably be between C and C sharp in the octave below that. (It is not unusual for the hum-note to be much sharper than this.)

In support of this statement let us take a few examples. 1. Take first the peal at Terling, in Essex, which consists of five bells in the key of F sharp, by five

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different makers, and of various dates, covering a period of 240 years. This is an excellent example, as, from the variety of makers and dates, any general characteristics that we may observe cannot be considered as peculiarities of "time" or "foundry." And it has further this great value, that the tones of these bells have been carefully analysed by Lord Rayleigh, and tabulated in his most valuable paper "On the Tones of Bells," printed in the *Philosophical Magazine* for January 1890. An examination of these tables gives the following results.

In the first three bells, including the oldest and the newest, the tones follow just the rule which I have called the "common" one—*i.e.*, they are nearly in octaves, but the fundamental is the flattest, the nominal sharper, and the hum-note the sharpest. In the fourth bell, the fundamental and the nominal are true octaves, and the hum-note is sharper by a long semitone. In the tenor, the fundamental and the hum-note are true octaves, and the nominal a semitone *flatter* (very unusual).

I claim this peal as a powerful witness to the truth of my position—(1) that the fundamental, nominal, and hum-note were *meant* to be in octaves, and (2) that, as a matter of fact, it is the exception to find a bell in which any two of them are in accord.

2. Take next the little peal of six bells in the church of Fittleworth, Sussex. Of these, three are new, the fourth is about fifty years old, the fifth and sixth very ancient. In each of the six, without exception, the

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nominal is a quarter of a tone, more or less, sharper than the fundamental. And, in all but one, the hum-note is a trifle sharper than the nominal; the exception being the tenor, a very ancient bell, in which the hum-note and the nominal are in unison. Can we help feeling that the general small defection from perfect octaves is an error from a *design* which is *fulfilled* in the exceptional case?

3. In the tower of Eastry, in Kent, are five bells, the tenor about a ton in weight. In *all* these the common rule, as stated above, holds good, with the exception that, in the fourth bell, the nominal is a shade *flatter* than the fundamental—an unusual case, but still tending to confirm the theory that these notes were meant to be true octaves.

4. There is a very fine peal of six bells in the tower of Stoke-by-Nayland, in Suffolk. Every one of these, with possibly one exception, follows the same rule: the nominals, fundamentals, and hum-notes being nearly in octaves, the hum-notes being the sharpest, the fundamentals the flattest, and the nominals between the two. The possible exception is the treble, which is slightly cracked, and the hum-note not observable.

5. One of the finest peals of eight bells in the kingdom is that of Lavenham, in Suffolk. Here also *every one*, with one notable exception, follows the same general rule of slightly imperfect octaves between the three principal notes; the errors in each bell being of the same kind—*i.e.*, all the hum-notes a little sharper, and the fundamentals a little flatter, than their respec-

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tive nominals. The one exception is the tenor, a marvellously fine-toned bell, which has, indeed, the reputation of being about the finest in England. In this, the fundamental and the nominal are apparently in perfect octave—a very noticeable fact, taken in connection with the reputation of this bell.

6. These are all instances of English bells. But, to guard against the supposition that these coincidences, or irregularities, are peculiar to our bells, I will mention next, a peal of eight bells cast at Louvain about eight years ago, and placed in the tower of Lower Beeding, near Horsham, in Sussex. I had an opportunity of examining these bells on their arrival in this country. There was much to learn from them, which I may hereafter refer to. But with respect to the point now before us—viz., the relative positions of the three principal tones—there was nothing to distinguish them from an ordinary English peal. There was the usual approximation to octaves, but I only noticed one instance in which the relation was true. In the seventh bell, the fundamental was a true octave below the nominal. But it was evident that this bell has been greatly altered, and I have reason to feel sure that, originally, the fundamental had been flatter than the nominal, as in most English bells, and as was, and is, the case with the tenor bell by its side.

7. To give one more instance, and this time of a French founder. There are four bells by Messrs. Paccard, of Annecy, in Savoy, in the Church of St. John, St. Leonards-on-Sea. They are remarkably

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good and sweet-toned, and are in much better tune with themselves than the generality of bells that I have examined. But still the same general errors are apparent. In three out of four, the nominals are a little sharper than the fundamentals, and the hum-notes decidedly sharper than the nominals. In the fourth and smallest bell, the hum-note and fundamental are practically in unison, but the nominal is notably sharper than either.

If now I have carried my readers with me so far, they will no longer be surprised at any difficulty they may have experienced in determining the note of any particular bell. For here we see that, in the *majority* of bells, we have three notes, very near to each other in pitch, though in different octaves, all struggling for the mastery, and each able—let me here say—under given circumstances, to assert its supremacy. Is it any wonder that even a skilled musician, if not learned in bell tones, should be in doubt as to the true note of a bell submitted to him? Is it so very surprising that "experts differed as to whether the note of the 'Gloriosa' bell was C sharp or D"?

I have not a doubt that the explanation of this is, that the sharper tone heard was the nominal, and the flatter the fundamental: this great bell following, in this respect, the common rule which we have so fully illustrated above.

"But"—I imagine my musical readers exclaiming—"if this be so, how is it that the sounds of bells are even tolerable? Any other instrument which gave forth

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simultaneously, *e.g.*, C, with a rather flat C sharp above and a rather flat D below, would be unbearable,—and the succession of a series of bells of this imperfect character would surely produce nothing but a hideous noise."

So one might think; but it is not so. For reasons which satisfy the learned in acoustics, the difference in quality of these sets of tones is such that they do not *interfere* with one another, so as to give the sense of discord, which we should expect. The tones of nominals, fundamentals, and hum-notes, seem to move, as it were, in three separate spheres. And though any discord, between at least the nominal and fundamental, in a bell cannot but seriously detract from the purity and fulness of its tone, it does not produce "beats," nor affect the ear painfully. Consequently, there are thousands of bells, having their principal tones quite out of tune with each other, which, *considered individually*, are good and pleasing. They might be made much better, perhaps; but as long as they stand *alone*, no alteration is necessary in order to satisfy the ordinary musical listener. You may listen to whichever tone you like—sometimes to one, sometimes to another; all are pleasing, and no *one* interferes with another.

But when it comes to peals and carillons, the case is different. In order to get any really musical effect, it is absolutely necessary that some *one*, at least, of the *sets* of tones in the series of bells should be properly in tune with itself—*i.e.*, all the nominals in tune with each other, or, similarly, all the fundamentals, or all the hum-notes.

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This, it is evident, is the very least that can be accepted. And, as a matter of fact, the choice is more restricted than this; for, important as are the hum-notes—far more important, as we are prepared to maintain, than either foreign or English founders seem to think—we are quite ready to allow that, unless *all three* sets are to be made to move in true octaves (which is devoutly to be wished), the "hum-note" set must be neglected, in comparison with either of the other two.

At this point, therefore—again to "lighten the ship"—we drop all reference to the hum-note for the present, and confine our attention to nominals and fundamentals.

We have then before us, let us suppose, a series of bells, direct from the foundry, all of the *common* character—*i.e.*, with the fundamental in each bell more or less flatter than its nominal—and, as is sure to be the case, with neither its nominals nor its fundamentals quite in tune with each other. Now, what shall we do? Plainly, the only really satisfactory operation, if it could be done, would be to bring the nominal in each bell into unison with its own fundamental, and then to tune each bell, so rectified, to its neighbour. This would indeed be "something like" tuning, and we are prepared to maintain that, in all ordinary cases, it can be done.

But, as a matter of fact (speaking generally) no one attempts such a thing. What is done is this: the tuner (consciously or unconsciously) selects one of the two sets of notes (either the nominals or the fundamentals), puts them in proper tune with each

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other, and leaves the other set untuned, either to the first set, or to each other.

To be more explicit—and I now ask the attention of my readers, *especially of those interested in carillons*, to what I now state—"The Englishman tunes the nominals, and neglects the fundamentals; while the foreigner tunes the fundamentals, and (comparatively) neglects the nominals."

Now, this difference of practice is a very remarkable fact, which I have never seen referred to in any of the many treatises on bells, nor have I ever met with any one who seemed to be aware of it. Yet it is as certain as it is interesting and important.

1. That the Englishman tunes a peal by the (so-called) "nominals" is shown beyond question by Lord Rayleigh in the paper referred to. The Terling peal is pronounced by English bell-experts to be in the key of F sharp. Well, the *upper* series of notes in those bells *is* in that key; and indeed I call this note the "nominal," because the Englishman *names* each bell according to the pitch of this note in it. The fundamentals of this peal form no musical series at all, and evidently have not engaged the attention either of the founder or the tuner.

But *any* peal of English bells will prove the same point. If the bells are what an English tuner calls "in tune," you will find that it is the nominals that are in tune, and not the fundamentals. I have often tried to call the attention of professional tuners to the fundamental of the bell they were tuning, but they invariably

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treated it with indifference. And there is, further, this curious fact: that while a tuner always gave the nominal as the note of any Bell, he invariably gave the pitch an octave lower than it really was. I have, for many years past, lost no opportunity of calling the attention of founders and tuners to these things, but I know not with what effect.

2. That the foreigner takes the fundamental as the principal note, and tunes the bells by it, is equally certain and unquestionable. The very fact that he calls it, as he does, the "fundamental" is almost conclusive. And no one can visit a Belgian foundry and engage in discussion about the bells without being convinced on this point. But we have clearer proof than this. The Belgian peal at Beeding was pronounced by the founders to be correctly in tune, and the seventh bell, in particular, they declared to be *exactly* in tune with the eighth. So it was, as to the fundamental; but, as regards the nominal, it was very flat, and the whole peal, generally, painfully out of tune to the English ear.

So also with the French bells of St. John's, St. Leonards. I took particular pains to discover from the founders whether the tenor and its octave were, according to their judgment, in perfect tune with each other. They assured me, on their reputation, that they were so, "exactly—to a vibration." Now these two bells are in exact accord as to their fundamentals, but the nominal of the treble is distinctly sharper than that of the tenor, so much so as to have

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attracted the observation of a resident, who called my attention to it.

Moreover, the internal form of foreign bells is such as to indicate how to sharpen them. But the effect of so doing is to sharpen the fundamental, without altering the nominal at all, or very partially.

I could adduce more evidence on this point, but this is, surely, enough.

The foreigner is, indeed, quite aware of the existence of the nominal, and, to hear him talk, you might think that he brought both sets into unison. But, except perhaps in very large bells, he really does not do so, as any one with an ear may judge, from the inharmonious character of Belgian carillons, as well as from such tangible examples as the Beeding and St. Leonard's bells.

One point more remains to be cleared up, before we can arrive at the practical conclusion we are seeking to reach. The foreigner tunes by the fundamental, the Englishman by the nominal: which is right?

A direct unqualified answer to this question is, as might be expected, impossible. Both are right in their way. But there is this difference: that while it *never* can be allowable to neglect the nominals, the fundamentals *may* be neglected in English *ringing* peals, and in the *upper* bells of carillons, not without some loss of purity and fulness of tone, but without *painful* injury to the harmonious effect. The reason for this distinction will appear from the following consideration.

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When bells are struck at considerable intervals of time, most persons would be apt to take the fundamentals as the notes of the bells, on account of their full and *persistent* character. But the case is different when one bell follows another in rapid succession. At the instant of striking, the keen sound of the (higher) nominal is most perceptible; and, if followed immediately by another, there is no time for the fundamental to force itself into prominence, and so the ear keeps following the nominals all through. This would be the case with an English peal, in which the bells follow one another very rapidly. And so also with the *higher* bells of a carillon, which take the "air." Consequently the nominals *must* be put into tune with each other in these cases. And it is the want of attention to this necessity which is the cause of the lack of harmony observable in foreign carillons.

But with the *lower* Bells of a carillon, the case is different. These strike, generally, at longer intervals, and the fundamental has time to assert itself, and to remain, so to say, master of the field. It therefore becomes necessary, in these bells, to tune the fundamentals also; and, of course, to bring them into unison with their respective nominals.

To sum up, then (omitting all reference to the hum-note)—

1. It is *essential* that *all the nominals*, throughout any peal or carillon, should be in tune with each other.

2. It is *very desirable*, in a *carillon*, that at least all the *heavier* bells (say, those above 7 cwt.) should have their

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fundamentals also brought into unison with their respective nominals.

3. It is *best*, in *all* cases, to bring the fundamental of each bell into true octave with its nominal, and then to tune the whole series of bells, *so rectified*, to each other.

Can this be done? I suggest, with some confidence, that, in all ordinary cases, it can. But this is another question, which I am not concerned to deal with in this paper. Bell founders and tuners naturally do not care to take any more trouble than is necessary in order to satisfy the public. It has been my object *to move the public to move the tuners*. If I succeed in that, I feel sure that the tuners will find out how to satisfy the demands made upon them, so far as the nature of the case admits.

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How to Cure Them.

On Bell Tones.

II.

THE object of my former paper was to place on record certain facts concerning bells as they are, and to call the attention of the musical public to them. And I did so, not merely in order to offer an explanation of the want of harmony observable in peals—and still more in carillons—but also in order to bring public opinion to bear on founders and tuners, so as to induce them to bring their bells into a more perfect agreement with the (presumed) intentions of the original designers of the present form of bell than has been thought necessary in the past.

But I did something more than this. I ventured on a pretty confident opinion that existing bells and peals might (generally) be so rectified as to be much more completely in tune, both with themselves and with each other, than we have yet found them.

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And here I desire to say, at the outset, that I am not a bell-founder. Had I been such, no doubt I should have kept any special knowledge to myself, and have made use of it for my own advantage. But, having no personal interests to serve, and believing it to be for the best interests of the art that the knowledge I have acquired, and which I hold to be essential to any real progress, should be at the command equally of all the profession, I have preferred to make a clean breast of all that I think I have learned, and let bell-founders take it or leave it as they may think best.

If, as I venture to hope, my account of things should prove correct and of value, I shall feel amply repaid if this is acknowledged (as no doubt it would be) by those to whom it may prove an important assistance in what is now a very obscure department of the bell-founders' art.

It will be remembered that the main point insisted on in the former article was that the tones which I have there designated as the nominal and the fundamental should in each bell be brought into unison with each other.

According to theory the nominal should be an exact octave above the fundamental. But, as a matter of fact, we rarely find it so, the nominal being very generally about a quarter of a tone (more or less) sharper than the fundamental; and the question is, "How to bring them together?"

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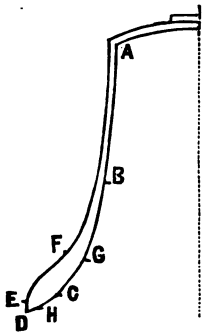

In order to explain my answer to this satisfactorily, I must direct attention to the figure.

This figure represents a half-section of a normal English bell.[1] The line A B C D represents the *inner* surface of the bell, and forms a continuous curve, the curvature of which becomes more acute as we approach the lip at D.

The line of the *outer* surface is more complicated, but is so ordered that the thickness of the bell shall be uniform from A to B, then gradually increase up to a point C, and then rapidly diminish until the bell terminates in a sharp "cusp" at D.

The points E and F indicate the position of certain "bead lines," which may be observed running all round a bell, which mark the boundaries of what is called the "sound-bow," or principal zone of the bell; and the points H and G are the corresponding points respectively on the inner surface.

We are now in a position to explain how to tune a bell—*i.e.*, how to alter its tones so as to bring them into harmony with each other, or with the corresponding tones in other bells.

It would evidently be inconsistent with the character of this Paper to enter into a detailed description of the

[1] Foreign bells (which probably represent an earlier type) differ from English in having the line C D straight instead of curved.

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various processes, and of the effect of each; but here is the whole matter in a "nutshell"—

The point H is the "turning-point" for tuning the nominal.

The point C is the "turning-point" for tuning the fundamental.

To be a little more particular:—

1. To *sharpen* the nominal, metal must be taken away (of course, all round the bell) from the little triangular portion H D E; by this means the nominal may be safely sharpened about $\frac{1}{8}$th of a tone. But the process rather spoils the *look* of a bell, and, for that and other reasons, is not popular with tuners. Nevertheless it is effective, and, within reasonable limits, quite allowable.

2. To *flatten* the nominal, metal must be taken off, all round the bell, from H to C, or to G, or even to B if necessary, thus *thinning* the main part of the bell; by this means the note may well be lowered as much as half a tone if required.

Now, these two processes are well known to all English experts, and I have never met with one who used any other; which shows, as I said before, that (consciously or unconsciously) English experts tune their bells to each other by the *nominals*, and by *no other* note.

And now for the fundamentals:—

1. To *sharpen* the fundamental, take off metal along the line C D; this may be continued until the line C E is reached.

2. To *flatten* the fundamental, take off metal from C to G, or even to B if necessary.

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And these are the processes used by foreign experts in tuning their carillons or peals; which, again, shows (as I said before) that the main object which *they* have in view, is to tune their bells to each other by the fundamentals, and *not* by the nominals.

If, now, the above rules are carefully studied, in connection with the figure, the following Possibilities, or Impossibilities—which I am unable here to establish at length—will, I think, be sufficiently apparent :—

1. That the fundamental cannot be flattened without also flattening to some extent, the nominal.

2. That the nominal *can* be flattened considerably without altering the fundamental—viz., by taking off metal, on both sides of C.

3. That the nominal can be flattened a *little*, while by the same process the fundamental will be a little sharpened, thus bringing the two towards each other—viz., by reducing the *rounded* surface C E to a flat surface.

4. That the fundamental can be sharpened considerably, while leaving the nominal nearly, if not quite, unaltered.

5. That although the process of sharpening the nominal will also raise the fundamental, it will not do so in the same degree; and would tend, therefore, to bring the two together, in the unusual (and very objectionable) case of the fundamental being originally the sharper note.

With these possibilities within our reach, it is surely evident that bells *can*, as regards these two principal

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tones, be put into tune with themselves and with each other. And if so, they can be so cast in the first instance.

Of course, in all this I am speaking *generally*. There are many bells so radically wrong that there is nothing to be done with them except "put up with" them, or send them to the melting-pot. And there are numberless cases of treble bells which, in order to make their leading tones *powerful* enough, have been made of a disproportionate thickness, with the inevitable result that their tones have been thrown very far out of due relation to each other. I fear that there is no help for this, and no effective method of dealing with such cases. There must be a *compromise* somewhere, and we have a tolerably clear idea as to what had best be sacrificed in order to effect it. All that I care to say here is, that the compromise must *not* be at the expense of the *nominal*. Whatever else has to give way, the nominals of these treble bells *must* be in tune with those of the rest of the peal.

And now, with due allowance for exceptional cases, I hope I have made out at least a very strong case to justify my appeal to the musical public—and especially to such as are incumbents or churchwardens—to demand from bell-founders a more perfect harmony in the bells supplied to them or tuned for them.

Why are we to submit to listen all our lives to a church peal which gives out two (not to say three) series of sounds, which ought to be in octaves, but which, all through the peal, are *about* a quarter of a

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tone apart? And I emphasise that word "about," because, if the error were *constant*, each of the series would be at least true in itself, though false to the others.

Are we to be told: "Oh! never mind the fundamentals—the nominals are all right, and that is all that is necessary?"

Well, but here is all Europe (practically) telling us to "never mind the *nominals* if the fundamentals are in tune."

They may be wrong in bidding us be indifferent to the nominals, but surely it savours of ignorance, or of "insular arrogance," to dismiss in this summary fashion the concensus of European opinion on the value of the fundamentals.

If the result of doing so were *satisfactory*, we might be content. But it is not so. No one who pays any intelligent attention to English peals can be satisfied with them as they are.

If the dissonance were *unavoidable*, we might submit to it. But it is not so. I am *certain*—and I think I have justified my opinion—that in most cases, probably in all important cases, it might be corrected.

Let incumbents and churchwardens, in particular, insist on a greater accuracy of tuning, and in time they will get it. Tuners will find out how to alter bells, if necessary, so as to bring about this unison between nominals and fundamentals; and then founders will learn experimentally how to alter their designs, so that bells should "come out" more nearly right at first.

Of course this means a good deal of intelligent pains-

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taking, and some little expense. But is not the object worth it? We may be sure of this, that the founder who first has the courage to grapple with, and the perseverance to solve, this problem, will get a name and reap a harvest which will amply repay him, and he will, further, earn the gratitude of all true lovers of music.

And here I must add a word in justice to myself, as well as to foreign professors of bell-tuning. I should be sorry to be thought ignorant of the intelligence and pains which many of them have bestowed on the regulation of the subordinate tones in their bells, and especially in the larger ones. I believe that they know a great deal that I am ignorant of. But I am certain that they make a great mistake in underrating the importance of the tone which I have called the nominal, especially in the case (so common with us) where it is sharper than the fundamental.

I believe that if they would only recognise the conspicuous importance of this tone—in such cases especially—even at the expense of the comparative neglect of some other tone, they would leave little to be desired in the carillons which are their peculiar pride.

It was no part of my original intention to enter upon the consideration of "thirds" and "fifths." But I may just say, in passing, that the "third" is far too important a tone to be ignored in the tuning, at least, of a large bell. When once its strident sound has caught the ear, it almost obliterates the other tones, and is sometimes, indeed, mistaken for the principal tone.

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All that I can say about it here is—

1. That some bells are cast with *major* "thirds" (more or less imperfect), and some with *minor*.

2. That a "third" cannot be sharpened; but may be flattened, by thinning the bell all round, from G towards B.

3. That in a peal of (say) eight bells, the "thirds" should be all major or all minor. This is considered correct; but we should rather like to hear a peal in which the "thirds" of the treble 4th, 5th and tenor bells are "major," and those of the rest "minor."

The "fifth," in like manner, cannot be sharpened; but may be flattened by thinning the bell all round, from B towards G.

And now a word about the tone which we have called the "hum" note—the deepest and most persistent of all the tones in a bell.

I have stated that this tone should be a true octave below the fundamental, and a double octave, therefore, below the nominal, thus forming the Bass note of the whole system. That it was really intended so to be, is surely manifest from the fact that it is found *nearly* to fulfil these conditions, in almost any bell; and that, in most cases, it is not more than half a tone sharper than the fundamental and a quarter of a tone sharper than the nominal.

I believe also that I shall be supported in my contention by Belgian experts, and moreover we have the authority of Helmholtz for the following statement:—"According to the observations of the organist Gleitz,

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the bell cast for the Cathedral at Erfurt, in 1477, has the following proper tones—*E*, *e*, *g*♯, *b*, *e'*, *g'*♯, *b c'*♯." And "Hemony of Zütphen, a master in the seventeenth century, required a good bell to have three octaves, two 'fifths,' one major and one minor 'third.'"

This, I think, should settle the question, not only of the hum-note, but of the whole theory of bell tones as set forth in these papers.

Before speaking of the method of altering the hum-note, so as to bring it into line with the other tones, I should like to say a word as to its practical importance.

The fact that it is the bass of the whole system of tones, in any perfectly attuned bell, ought to be sufficient. And though it is not so loud as the fundamental, nor so clear as the nominal, it is impossible that any want of agreement with these should not injure the general effect, especially if in a *series* of bells these great "booming" tones do not rise and fall fairly evenly with the others. In the case of large slow-striking bells of clocks, or carillons, this want of agreement with the other tones must be specially objectionable, as the hum-notes are, as we have said, the most *persistent* of all.

But their general importance may be made clearer by the following illustration :—

Sitting in my dining-room, with outer and inner doors shut, I was struck by the singularly sweet sound of our six little Fittleworth bells as heard down the chimney. On opening the doors, so as to hear them *directly*, I observed with surprise that the scale was

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different; and I finally discovered that what I had heard down the chimney were the hum-notes, which *alone* found their way to me by this devious course.

After this experience, we cannot dismiss the hum-notes as unworthy of careful attention.

How to govern them and bring them into unison with their proper fundamentals and nominals? is a question which I am not prepared to answer with quite the same certainty as in the case of the other tones. To be able to do so, we must first determine on what proportions of the bell its "pitch" mainly depends.

Now, in the case of the other tones this is sufficiently known; and it is from this knowledge that we are able to deduce the rules for altering them, as given above.

But there is a mystery about the production of the hum-note which has not yet been quite cleared up. I give here my own belief, founded on observations which I cannot here describe at length.[1] I believe, then, that, whereas each of the other tones may be referred principally to some particular *portion*, or zone, of the bell, the hum-note is, in a peculiar sense, the tone of the *whole mass* of the bell. And I have come to the following conclusions as to its government:—

1. That this tone can never be sharpened.

2. That it may be flattened to any reasonable extent by thinning the walls of the bell near to the crown—*i.e.*, near to A in the figure.

3. That, possibly, the proportion of the "length" of the bell to its "width" may have some bearing on the

[1] See Appendix.

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relation of the hum-note to the other tones; any shortening of the length in proportion to the other dimensions having the effect of sharpening the hum-note.

And let me here say that there is a special reason why the government of the hum-note should receive the attention of founders. It has for long been a source of perplexity and vexation that *small* bells—such as those added to a peal of eight to make a peal of ten—are apt to behave in a very erratic fashion; appearing to sound much sharper than they were intended to be, or were believed to be. I am satisfied that, in most cases, the secret of this apparent anomaly lies in the fact that in these bells the hum-note is (for reasons not far to seek) excessively powerful, and being (as usual) sharper than the nominal, overpowers that note, and "takes the field," thus giving the result complained of.

The cure is—to flatten the hum-note till it is in unison with the nominal, when I believe the dissonance will disappear.

If, as I have suggested, this may be done by casting such bells a little "longer," a double advantage will be gained. Not only will the harmony be (so far) perfected, but the additional length of these upper bells will render them far more convenient for ringing with the other larger bells.

These are points, however, which can be easily settled by any bell-founder; and should they turn out as I suggest, the whole problem will be solved; and, thenceforward, no founder ought to permit at least any

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large clock-bell to leave his hands which has not its hum-note, fundamental, nominal, "third" (and perhaps "fifth"), in harmony with each other.

I know of no such bell at present. Who will be "first in the field" to produce it?

But though I do not know of any completely attuned bell, I should wish to do justice to modern founders; and I am bound to say that, as a rule, the bells produced nowadays by our best founders are more nearly in harmony than are the majority of our *old* church bells; especially is this the case with *large* bells.

A remarkable instance of this may be heard any day by dwellers in London, I refer to the Great Bell of St. Paul's Cathedral. This bell, weighing nearly seventeen tons, hangs in one of the western towers, and is rung every day at 1 p.m. Its position in the tower, sunk as it is so much below the orifices, is very unfavourable to its "carrying" power, and to the *even* development of its tones. Nevertheless, it can be heard very well from any point of the space round Queen Anne's Statue.

I have tested this bell, as far as my instruments would permit, with the result that I have found all the tones, so far, in perfect accord: *i.e.*, the fundamental and the nominal are in true octave, each being a true E♭. The tone next above the fundamental is also in perfect tune with it, but with this peculiarity—that the note, instead of being a "third" above the fundamental, is a "fourth," *i.e.*, A♭ instead of G or G♭. This is a pity; and the more so that, from the position of the bell in its tower, this tone is heard in undue proportion to the others.

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Nevertheless, the general effect is musical, and very pleasing.

The hum-note of this great bell was too deep for a scientific test by any instrument within my reach, but it appears to be in complete unison with its fundamental. altogether, this bell is a very noble specimen of modern English bell-founding.

Since writing the above I have met with two more bells which appear to be in perfect tune as to their three principal notes. (1) The Tenor of the Church of Handsworth, near Birmingham, which seems to have also its third and fifth in perfect tune, though otherwise not a remarkably good bell. And (2) the old sanctus bell of Chichester Cathedral. An interesting bell, if only from the fact that it fell with the spire in 1852, and was recovered uninjured.

There still remains one very important matter to be considered, which has already, no doubt, suggested itself to those who have had the patience to read these papers. "How," it will be asked, "are we to discriminate with accuracy, all these various tones, so as to be able to compare them, and note the various degrees of error?"

This is a most pertinent inquiry, for unless this can be done I am confident that any knowledge of the methods of *altering* these several tones will be practically useless. And more, had I not possessed some method of eliciting *each* tone, separately, I should never have attained what knowledge I have on this subject.

The method which I have used for about twenty-three

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years, I am aware, is not unknown to others; but as far as I am concerned, is my own invention, quite effective, and very simple to those who know how to use it.

But it is not merely a piece of information to be imparted by words, but rather an art to be learnt; and I am somewhat unwilling to risk the probability of its being pronounced "a failure" by those who, acting on a mere verbal description, should make nothing of it.

I will only say that the principle of it is that known as "vibration by sympathy," it being a fact that any note in a bell can be elicited separately by touching the bell with the stem of a vibrating fork which is of the same pitch as the note in question.

I think that few are aware of the value of this little experimental fact, and it is not everyone who would have the patience and skill to apply it successfully. If my services were desired, by founders or others, for such guidance as I could give, I would try and arrange with them, and I can promise to founders a most valuable help in their difficult work, and to any lover of music a fruitful source of interest and pleasure.

A. B. SIMPSON.

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Appendix.

ON THE GOVERNMENT OF THE "HUM," OR "BASE-NOTE," IN BELLS.

THAT the subordinate notes in bells are not true harmonics of the principal note, is manifest at once to the ear.

On the other hand, if the various tones are respectively, in any degree, the special products of distinct parts of the bell, it is clear that—all the parts being in rigid connection with each other—no tone can be, absolutely, independent of the rest. In other words, it would seem impossible that any one tone in a bell could be altered without affecting (in however small degree) the whole system.

But these unintentional alterations of tone may be very slight, and even inconsiderable.

If then it can be determined, in the case of each separate tone, the particular part of the bell of which it is (mainly) the product, it may be possible so to alter the particular parts as to bring (if required) the various tones into harmonic relations; and therefore to cast a future bell with these relations correct, from the first.

The Abbé Bachman, who represents the Louvain Foundry, writes thus—"A bell must be considered, theoretically, as a series of superposed rings—at superposed metallic zones, vibrating separately, and producing each its own

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tone, according to its diameter, and in proportion to its thickness of metal; a slight alteration in these elements, in the curve of the bell, has influence on the height of its tune."

He means undoubtedly by this that

The "sound-bow" is the zone which produces the "fundamental."

The lower "waist" is the zone which produces the "third."

The upper "waist" is the zone which produces the "fifth."

And (I suppose) the "crown" is the zone which produces the "octave" or "nominal."

And there is no doubt that to a great extent he is right. For there is no question that, as regards the *first three* of these, the reduction of the metal on these zones does lower the pitch of these tones respectively.

But, if the relative thickness and diameter of these zones govern the fundamental, third, and fifth, what parts of the bell are left to which we can refer the government of the "nominal" and of the hum-note?

Now, as regards the "nominal," I cannot but think that, like the fundamental, it is the direct product of the "sound-bow"—under the restraint, no doubt, of other portions of the bell. At any rate, what sharpens the "nominal" (if anything) *sharpens* the fundamental, and what flattens the fundamental, flattens also the "nominal." At the same time, it is noticeable that both sharpening and flattening of the "nominal"—the former exclusively, and the latter slightly—can be effected by restricting our operations to the extreme zone of the bell, viz., to that part extending beyond the circle of "percussion" to the lip.

It seems then that the tone of this *highest* note has some special connection with this extreme zone.

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Is it possible that the deepest note—the hum-note—should be specially related to the other end of the bell—the crown? For we cannot help enquiring, "Where is its 'habitat'?" Of what part of the bell is the hum-note the special product? Or (which is the practical point we are aiming at) what part (if any) of the bell must we operate upon in order to alter the pitch of the hum-note so as to bring it into true relations with the other tones, if necessary?

Now it has long seemed to me that the hum-note is, in some special sense, the note of the *whole mass* of the bell. I have been led to think this (1) partly because no special part of the bell remained unappropriated to which we could refer it. (2) Partly because this note is so much deeper than the fundamental, which is certainly the product of the principal part of the bell—the sound-bow. (3) Partly because I observed that if the bell-frame receives a jar—thus causing a general tremor of the bell, without the *special* excitement of any *part*, it is the hum-note which is elicited.

Such being the direction of my thoughts, it was with great interest that I read the following observation by Helmholtz: "The *body* of the bell, when struck, gives a deeper sound than the 'sound-bow,' but the latter gives the loudest tone."

Helmholtz is certainly here speaking of the hum-note, which he attributes to the 'body of the bell'—*i.e.*, to the whole mass of the bell-proper.

Then further, I had often observed that in ordinary tuning-forks there are notes which curiously correspond with the hum-notes, and fundamentals (or nominals) in bells.

Thus, if any fork is held lightly in the hand, by the stem, and is struck sharply, with a hard substance, about the middle of either limb, it gives out a very high and piercing, though sweet note—quite different to that emitted by the fork when,

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being in a state of excitement, the stem is pressed upon the table. The "striking" note disappears almost immediately —like the nominal in a bell—but the lower note—like the hum-note—continues persistently.

It seemed to me, then, that in the low, persistent note of a fork we have something analogous to the hum-note in a bell; each being the lowest note produced by a vibrating instrument, and each, apparently, the product of the *whole body* of the instrument proper.

My next thought was that a bell might be considered as generated by the revolution of a fork of peculiar shape—*i.e.*, that of a vertical section of a bell—the stem being supposed to be attached to the centre of the crown, and the question arose—"Could not the pitch of the hum-note of a bell be governed in some such way as the *corresponding* note of a *fork?*"

Now as the hum-note is (almost) always too *sharp*, we need only consider the case of having to flatten it. Referring, then, to the analogous case of a tuning-fork, we know that this can be flattened—

1. By *weakening* the limbs of the fork near to where they spring from the stem.

2. By *lengthening* the limbs of the fork, which may be done by working a file down into the cleft of the fork.

The analogous operations to these in the case of a bell would be—

1. To pare out metal all round inside the bell near to the points (or circle) where the body of the bell unites with the crown; or

2. To recast the bell *longer in the waist*, the other elements remaining the same.

My suggestions in the second paper are the result of this train of thought.

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The reasoning is, no doubt, open to criticism, but that the conclusions to which it led me are correct I have little or no doubt.

Neither process can well be tried except by founders, or those who have special apparatus. The first has been tried, and I believe with success.

As to casting bells *longer*, it is well to know that bells are hardly ever now cast so long in proportion to their width as was thought correct at one time. But there still exist a few of these "long bells." I know of but two—one a very small bell in Egdean Turret, and the other is the "Sanctus bell" of Chichester Cathedral, mentioned above. It is remarkable that in both these bells the hum-note is in unison with its fundamental; whereas in the case of almost every "short bell" the hum-note is, as we have abundantly seen, too sharp.

One cannot help suspecting that this almost universal sharpness of the hum-note is the unintended and unobserved result of shortening bells for the sake of convenience in ringing.

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Why bells sound out of tune and how
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